

A REFERENCE BOOK  
FOR THE MECHANICAL ENGINEER, DESIGNER,  
MANUFACTURING ENGINEER, DRAFTSMAN,  
TOOLMAKER, AND MACHINIST

26<sup>th</sup> Edition  
Machinery's  
Handbook

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### **MACHINERY'S HANDBOOK**

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## ACKNOWLEDGMENTS

The editors would like to acknowledge all those who contributed ideas and suggestions to the *Handbook*. Several individuals and companies, in particular, contributed substantial amounts of information to this edition.

Dr. Bertil Colding, Colding International Corp., Lansing, Michigan provided extensive material on grinding speeds, feeds, depths of cut, and tool life for a wide range of materials. He also provided practical information on machining econometrics, including tool wear and tool life and machining cost relationships.

Dr. Bruce Harding, Director and Professor of MET, Purdue University contributed information on GD&T as well material on the differences between ISO and ANSI surface finish symbology.

Mr. Edward Craig of WeldTrain International and ABB Flexible Automation, Inc. contributed information on pipe welding.

Mr. Sydney Kravitz provided valuable information on the weight of piles for different materials.

Dr. T. A. Stolarski, Professor at Brunel University, provided detailed explanations and equations on aerodynamic lubrication.

Mr. Alec Stokes provided much new material that was incorporated into gearing sections including highpoint gears, British spur and helical gearing, addendum modification to involute spur and helical gears, and hypoid gears.

Mr. Richard Pohanish contributed material on metal working fluids.

Hansvedt Industries provided a detailed listing of EDM terms.

Mr. Matthew Radcliff supplied data on wood screw pilot hole sizes.

Mr. Robert E. Green, as editor emeritus, contributed much useful, well organized material to this edition. He also provided invaluable practical guidance to the editorial staff during the *Handbook's* compilation.

Finally, Industrial Press is extremely fortunate that Mr. Henry H. Ryffel, author and editor of *Machinery's Handbook*, continues to be deeply involved with the *Handbook*. Henry's ideas, suggestions, and vision are deeply appreciated by everyone who worked on this book.

For more than 85 years of continuous publication, *Machinery's Handbook* has served as the principal reference in design and manufacturing facilities, and in colleges throughout the world. The editors' objective continues to be that of making the *Handbook* a practical tool to be used in the same way that other kinds of tools are used, to make or repair products of high quality, at the lowest cost, and in the shortest time possible.

Reference works such as *Machinery's Handbook* cannot carry the same information in successive editions if they are to justify the claim that new or updated material is always presented. The editors of such a book must move with the times, keeping a finger on the pulse of manufacturing industry to learn what subjects have less, and what have more, usefulness to the majority of users. At the same time, material that is of proven worth must continue to be included if the *Handbook* is to provide for the needs of disciplines that do not develop as fast as, for instance, the numerical control field. Thus, it remains a difficult task to select suitable material from the almost limitless supply of data pertaining to the manufacturing and mechanical engineering fields, and to provide for the needs of design and production departments in all sizes of manufacturing plants and workshops, as well as those of jobbing shops, trade schools, and technical schools.

The editors rely to some extent on conversations with users of the *Handbook*, and on postcards and other written communications from *Handbook* users, for guidance on which topics should be introduced, revised, lengthened, shortened, or omitted. In response to users' suggestions, in recent years material on logarithms, trigonometry, and other topics was restored, and in this edition sine-bar tables have finally been restored after numerous requests for this topic. Also at the request of users, in 1997 the first ever large-print or "desktop" edition of the *Handbook* was published, followed in 1998 by the publication of *Machinery's Handbook CD-ROM* including several hundred additional pages of material restored from earlier editions.

Regular users of the *Handbook* should be able to identify some of the many changes embodied in the present edition. "Old style" numerals, in continuous use since the first edition, and occasionally a source of confusion for readers, have been replaced by a modern numeral style. The entire text of this edition, including all the tables and equations, has been reset, and a great many of the numerous figures have been redrawn. The addition of 80 pages brings the total length of the book to 2640 pages.

The 26th edition of the *Handbook* contains significant format changes and major revisions of existing content, as well as new material on a variety of topics including: aerodynamic lubrication, high speed machining, grinding feeds and speeds, machining econometrics, metalworking fluids, ISO surface texture, pipe welding, geometric dimensioning and tolerancing, gearing, and EDM.

Other subjects in the *Handbook* that are new or have been revised, expanded, or updated are: graphic descriptions of functions of angles, imaginary and complex numbers, complex coordinate systems, contour milling, weight of piles, Ohm's law, binary multiples, force on inclined planes, and measurement over pins.

Those users involved in aspects of machining and grinding will be interested in the new topics *MACHINING ECONOMETRICS* and *GRINDING FEEDS AND SPEEDS*, presented in the *Machining* section. The core of all manufacturing methods start with the cutting edge and the metal removal process, and improving the control of the machining process is a major component in order to achieve a **Lean chain** of manufacturing events. These sections describe the means that are necessary to get metal cutting processes under control and how to properly evaluate the decision making.

A major goal of the editors is to make the *Handbook* easier to use. The 26th edition of the *Handbook* continues to incorporate the time-saving thumb tabs, much requested by users in the past. The table of contents pages beginning each major section, first introduced for the 25th edition, have proven very useful to readers. Consequently, the number of contents pages has been increased to several pages each for many of the larger sections, more thor-

## PREFACE

oughly reflecting the contents of these sections. In the present edition, the Plastics section, formerly a separate thumb tab, has been incorporated into the Properties of Materials section. A major task in assembling this edition has been the expansion and reorganization of the index. For the first time, most of the many Standards referenced in the *Handbook* are now included in the index.

The American Standards Association was reconstituted in August 1969 as the United States of America Standards Institute, and standards that had been approved as American Standards were designated as USA Standards. In October 1969, the name was changed to the American National Standards Institute. Thus, the designation of present standards is ANSI instead of ASA or USAS. Standards originally adopted by the American Standards Association and not revised are still referred to in the *Handbook* by the designation ASA.

ANSI Standards are copyrighted by the American National Standards Institute, West 42nd Street, New York, NY 10017, from whom current copies may be purchased. Many of the American National Standards Institute (ANSI) Standards that deal with mechanical engineering, extracts from which are included in the *Handbook*, are produced by the American Society of Mechanical Engineers (ASME), and we are grateful for their permission to quote extracts and to update the information contained in the standards, based on the revisions regularly carried out by the ASME. Information regarding current editions of any of these Standards can be obtained from ASME International, Three Park Avenue, New York, NY 10016.

Users who call possible defects to the attention of the editors, or the omission of some matter that is considered to be of general value, often render a service to the entire manufacturing field. We desire to increase the usefulness of the *Handbook* as far as possible, so all criticisms and suggestions about revisions, omissions, or inclusion of new material are welcome.

Christopher J. McCauley, Editor